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Delay Discounting: Are Magnitude Effects Moderated by Domain Effects?

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A thesis submitted to the Graduate Faculty of

JAMES MADISON UNIVERSITY

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Table of Contents

List of Tables	iii
List of Figures	iv
Abstract	v
Introduction.....	1
Method	15
Results	16
Discussion	17
References	23
Tables and Figures	26
Appendices.....	31

List of Tables

Table 1: Individual R^2 values across commodity types	26
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List of Figures

Figure 1: Equation 2 Curve Fits Across All Conditions at Median Level of Analysis29

Figure 2: Visual Analysis of AUC Values.....30

Abstract

Delay discounting is a phenomenon wherein a commodity loses its value as the delay to its receipt increases. It may be conceptualized as a measure of patience, or impatience. There are several aspects of a commodity that contribute to its loss in value, in addition to the delay to its receipt. Specifically, there are differential rates in delay discounting across commodity types (domain effects) and commodity amounts (magnitude effects). Interestingly, magnitude effects occur almost exclusively in relation to a particular commodity type: monetary rewards. The present study sought to isolate magnitude effects from a particular quality of monetary rewards: fungibility. A 2X3 within subjects ANOVA was used to examine the relation between conditioned reinforcer amount (\$100 and \$1,000) across a range of differentially fungible outcomes (VISA gift cards, gift cards to Old Navy, and gift cards to Old Navy that can only be exchanged for socks). There was a significant magnitude effect, where large amounts were discounted less steeply than small amounts. There was also a significant effect of reinforcer fungibility. The least fungible outcome (gift cards to Old Navy that can only be exchanged for socks) was discounted the most and differed significantly from the more fungible outcomes (Old Navy gift cards and VISA gift cards), which, in turn, were not significantly different from each other. Given the current findings, alternative delay discounting research paradigms are proposed—future research should consider holding conditioned reinforcer amount constant across a range of more systematically manipulated fungible outcomes.

Keywords: patience, delay discounting, domain effects, magnitude effects, fungibility

Delay Discounting: Do Domain Effects Moderate Magnitude Effects?

When faced with a choice between two or more options, it is often the case that each of the options is associated with a qualitative or quantitatively different consequence. The consequences of choice may be described as being more or less optimal depending on the outcomes they produce. Some consequences may lead to maximally optimal outcomes, whereas other consequences are associated with suboptimal outcomes. Some researchers have referred to maximally optimal choices as rational choices and suboptimal choices as irrational choices. Rational and irrational choices may be conceptualized as representing two ends of a continuum of adaptive behavior. For example, irrational choices have been shown to be correlated with certain pathological disorders such as substance use and gambling, whereas rational choices are correlated with higher socioeconomic status (Green, Myerson, Lichtman, Rosen, & Fry, 1996; MacKillop & Kahler, 2009; Madden & Bickel, 2010).

However, assuming that irrational choices are made across a continuum, it may be argued that irrational decisions are not made exclusively by people who display high levels of aberrant behavior. Consider a person who chooses to spend all of his or her money today, instead of saving or investing. Is this person making an irrational decision? On the one hand, making a choice to invest today allows for a greater amount of money later. On the other hand, what if this person had to spend all of his or her money that day in order to feed his or her family? Would knowing that piece of information change the way in which someone chose to label his or her behavior? There are likely many different domains to the construct of rationality, and if there is an answer to the aforementioned

question, it is likely a multifaceted one.

Because of the complex nature of the decision-making process, it is necessary to study and focus on fundamentally separate facets of rational choice. Delay discounting—a robust phenomenon in the decision-making literature— provides a framework for a behavioral measure of an individual’s impulsivity (or self-control). However, impulsivity is hard to operationally define and implies a level of mentalistic explanation. Recently, Green and Myerson (2013) suggested that there are (at least) two fundamentally separate facets of impulsivity: patience (or impatience) and risk (or risk aversion). In the context of that argument, delay discounting may be said to be a measure of patience (or impatience) and is most accurately defined by a decrease in the subjective value of a commodity as the delay to its receipt increases.

Delay discounting can be measured using a binary choice procedure, wherein a person is asked whether he or she would prefer to receive a quantitatively smaller amount of a commodity immediately, or wait to receive a quantitatively larger amount of the same commodity after a delay. The amount of the smaller more immediate commodity is then adjusted on each subsequent choice question in order to make it more or less appealing. For instance, if a person chooses the larger/delayed outcome, then the amount of the smaller/immediate outcome is increased in the next choice question, thus making that alternative more appealing. Alternatively, if the person chooses the smaller/immediate outcome, then the amount of the smaller/immediate choice alternative is decreased in the next choice question, thus making that alternative less appealing. This process is continued throughout a series of choice questions. Each choice that a person makes narrows the possible range of values that the smaller/immediate reward can take

on. The value of the smaller/immediate alternative at the end of the choice series is said to be an estimate of choice indifference, or the point at which that particular person is indifferent between receiving the smaller/immediate reward and the larger/delayed reward. This indifference point is then plotted as a function of that particular standard delay condition (the delay to which the larger reward could be received). This process is then repeated for a series of different standard delay conditions, allowing for a visual representation of how a commodity loses its value as the delay to its receipt increases. However, a visual representation of delay discounting is only so useful, especially when trying to make comparisons. In order to be more precise, researchers use mathematical/algebraic functions to fit, describe, and predict the delay discounting of future outcomes. The section below will describe the mathematical approaches that have been used in delay discounting research.

Theoretical Quantification

There are two main mathematical models that have been used to quantify delay discounting: the exponential decay function and the hyperbolic decay function. Both of these models are similar in that they use the same parameters; they differ in terms of the relation between the parameters (particularly delay and value). The parameters shared in these models include: V — the subjective value of the commodity; A — the amount of the commodity; D — the delay to which the commodity is received; and k — free parameter and index of discounting. Larger k values are indicative of steeper discounting (or lower patience) and smaller k values are representative of shallower discounting (or higher patience). It is important to note that the absolute value of k fluctuates as a function of amount (A), so larger values of A will necessarily have higher k values (e.g. Estle, Green,

Myerson, & Holt, 2006; Green, Myerson & Mcfadden, 1997).

The exponential decay function:

$$(V=Ae^{-kD}) \quad (1)$$

is primarily used by economists and was arguably the first model used to describe delay discounting (Green & Myerson, 1996). This model assumes “rationality,” proposing that there is consistent and direct relation between V and D , meaning that for every unit of delay there is a decrease in value, and this decrease is constant across all possible values of D . However, Green and Myerson (1996) noted several problem with the exponential equation. First off, the exponential equation does not take into account amount-dependent delay discounting, or magnitude effects (discussed later). Also, the exponential model overestimates subjective values at longer delays, and underestimated subjective value at shorter delays. Fortunately, there other models that better fit delay discounting data.

The hyperbolic decay function:

$$V=A_i/(1+KD_i) \quad (2)$$

was originally derived from the simple reciprocal equation: $V_i = A_i/KD_i$ (Mazur, 1987). This equation assumes that subjective value is directly proportional to the amount of a commodity and inversely proportional to the delay to the receipt of that commodity. However, the simple reciprocal model is not sufficient for describing delay discounting, because the line curves up and away from the x-axis, suggesting that as the delay approaches 0, subjective value is infinite. This problem is ameliorated in the hyperbolic function by adding an integer value of 1 to the denominator, causing the function to asymptote along the y-axis instead of concaving inward. As opposed to the exponential equation, this model weighs in the effects of amount on the decreasing subjective value

rewards, being that larger amounts of money have been observed to be discounted less steeply than smaller amounts of money. Because of this adjustment, the hyperbolic equation does a much better job at estimating subjective values at larger delays in particular and therefore accounting for preference reversals. Because of this, this model consistently accounts for more data variance than the exponential model, by more accurately predicting subjective values at larger delays (Green & Myerson, 1996).

A derivation of the hyperbolic equation referred to as the “hyperboloid” or “hyperbolic with subscript”:

$$V=A_i/(1+KDi)^s \quad (3)$$

equation adds a second free parameter (s exponent) to the denominator, allowing for more “flexion” to the curve at shorter delays. Although this parameter is not currently known to have true “psychological” value, it serves as a non-linear scaling parameter and allows for a higher percentage of explained variance in the indifference curve at both the individual and group levels (but only in human models of delay discounting) (Green & Myerson, 1996). However, some behavioral scientists argue that a more parsimonious equation (e.g. one with fewer free parameters) is more accurate. Regardless, further analyses are necessary to understand the psychological value of the subscript.

There are issues with using mathematical models as a means to quantify delay discounting. Even though one type of model (hyperboloid) describes more data variance than the others, there is no unified agreement as to which mathematical function should be used (Green, Myerson, & Warusawitharana, 2001). The exponential model holds that there is a consistent decrease in value across increasing units of delay, whereas the hyperbolic model suggests that the decrease in value as a function of delay is weighted by

the amount of the commodity being discounted. Furthermore, the interpretation of the parameters used in these models may sometimes be problematic. For example, consider a situation wherein Equation 3 is used to compare delay discounting across two groups (e.g. gamblers and non-gamblers). Assuming there is a difference in discounting between these groups, this difference could be the result of either differences in k or s . Being that these two parameters represent two different processes (one of which representing a differential rate in delay discounting, the other being a scaling parameter, the behavioral processes of which are currently unknown), constructing an argument for differential rates in delay discounting for these two groups may be problematic. Furthermore, there may be considerable variance around each indifference point for a particular individual. If that is the case, then the individual discount parameter may be skewed, and aside from a graphical representation of the individual data that includes error bars, there is no accurate way to plot this large amount of data variance in a single data point. Also, the individual discount parameter k necessarily fluctuates with differing amounts (A). Although statistical approaches are not traditionally used in the experimental analysis of behavior, the two aforementioned issues make inferential statistics unavoidably problematic.

Atheoretical Quantification

Calculating area under the curve (AUC) is a way to quantify discounting without having to address the aforementioned theoretical issues. AUC is atheoretical, meaning that (in the context of delay discounting) it avoids using mathematical parameters that are assumed to contribute to the decrease in value as a function of time. In addition to avoiding theoretical issues, this approach may be useful in comparing rates of

discounting when there is no mathematical function that fits the data. Also, AUC values are continuous variables that lend themselves well to statistical analyses. The AUC approach may be a bit deceiving in that there is actually no curve fitting in this process. However, if one were to calculate an AUC after curve fitting, then generally speaking, steeper curves (and thus lower AUCs) are indicative of a propensity to choose the smaller choice alternative, whereas shallower discount functions (with greater AUCs) are indicative of a greater propensity to choose the larger, more delayed reward. Calculating the AUC starts by normalizing the data so that the value (amount of reinforcement or adjusting delay value) falls on a scale from 0 to 1, and plotting the data points on a graph. Next, connecting each data point results in a set of trapezoids that will allow for the summation of the area below the data points. We may calculate the area of each trapezoid by using the formula:

$$[(x_2 - x_1)(y_1 + y_2)/2] \quad (4)$$

where each “x” is a successive delay, and y₁ and y₂ are the subjective values of those particular data points. By summing the area of each trapezoid in our graph, we calculate our AUC.

Patterns of Discounting: Commodity Amounts

One area of discounting research has examined delay discounting across quantitatively different amounts of the same commodity, specifically hypothetical and actual monetary rewards. Thaler (1981) examined delay discounting across small and large amounts of hypothetical monetary rewards (\$15, \$75, \$250, \$1200, and \$3000), framing the questions such that the participants were to imagine themselves winning lottery money, and they could take a smaller amount of money now or wait to have a

larger amount of money later (1 month, 3 months, 5 years, 6 years, and 10 years). The experimental design was between-groups, with three groups of participants receiving questions about different constructions of the possible larger/delayed outcomes listed above. Thaler's results suggested that, as the delay and amount of money increased, discounting rates decreased.

In a completely within-subjects design, Green, Myerson, and Macaux (2005) had people choose between a smaller/ more immediate hypothetical monetary reward and a larger/delayed monetary reward. The conditions in this experiment differed both in terms of the amount of money to be received in the large/delayed condition (\$200, \$10,000), as well as the inter-reward delay (0 years, 2 years, 5 years, and 10 years), or the difference in time at which the smaller/immediate reward and larger/delayed reward may be received. The authors fit the hyperboloid equation to the data and found that the larger amount of money was consistently discounted less steeply than the smaller amount of money. In a similar procedure, Green, Myerson, and McFadden (1997) examined delay discounting of different amounts of money (\$100, \$2,000, \$25,000, and \$100,000) across a series of delays (1 year, 3 years, 5 years, 10 years, and 20 years). The authors fit the data to both the exponential and hyperbolic equations and found that the hyperbolic function consistently provided a better description of the data. Additionally the authors found that larger amounts of money were consistently discounted less steeply than smaller amounts of money.

This same pattern of results has also been found across different populations. Green, Fry, and Myerson (1994) looked at discounting rates in small and large amounts of hypothetical monetary rewards across different age groups (children, young adults, and

older adults). Specifically, they asked all participants to choose between a smaller/immediate amount of money and a large/delayed amount of money. Larger/delayed amounts varied across conditions and groups—children were asked questions about \$100 and \$1000, while young and old adults were asked questions about \$1,000 and \$10,000. For all participants, the larger/delayed alternative conditions were 1 week, 1 month, 6 months, 1 year, 3 years, 5 years, 10 years, and 25 years. Consistent with the pattern of previous results, smaller/immediate amounts of hypothetical monetary rewards were discounted less steeply than larger amounts of money. They also found that older individuals discounted less steeply than younger individuals.

Expanding on these findings, Green, Myerson, Lichtman, Rosen, and Fry (1996) looked at the delay discounting of small and large amounts of money across age groups and income levels including: upper income younger adults, upper income older adults, and lower income older adults. The delays and amounts of hypothetical monetary rewards for the larger/delayed outcome conditions were the same as the adult conditions used in Green et al. (1994). Again, larger amounts of hypothetical monetary rewards were discounted less steeply than smaller amounts of hypothetical monetary rewards, and older individuals discounted less steeply than younger individuals. Additionally, income level moderated rates of delay discounting: People who belonged in the lower income group showed steeper discounting than people who belonged to higher-income groups. Collectively, these results provide evidence that there are differential rates of discounting across quantitatively different amounts of the same reinforcer. This phenomenon has been referred to as a magnitude effect.

Patterns of Discounting: Commodity Types

Delay discounting has also been examined across a wide variety of commodities other than money, including: alcohol, cigarettes, food, and health to name a few (Chapman & Elstein, 1995; Odum & Baumann, 2007; Odum & Rainaud, 2003). For example, Chapman and Elstein (1995) compared discounting across several commodity types: health, vacation, and money. This was done by asking subjects to choose between smaller/immediate outcomes and larger/delayed outcomes. Questions about vacation and health outcomes were framed in terms of a monetarily equivalent amount of the respective outcome. Their findings suggested that health outcomes were discounted more steeply than vacation outcomes, and both vacation and health outcomes were more steeply discounted compared to monetary outcomes. Other studies have examined discounting rates across money and substances of abuse in different populations. For example, when given a 1 in 6 chance to actually win the monetary amount chosen in a delay discounting task, Kirby, Petry, and Bickel (1999) found that opioid-dependent individuals discounted money more steeply than matched controls. Expanding on these findings, Madden, Petry, Badger, and Bickel (1997) examined the delay discounting of hypothetical monetary rewards in opioid-dependent individuals, as well as non-drug-using matched controls. Opioid-dependent individuals were also asked questions about hypothetical amounts of heroin. Compared to the non-drug using control participants, opioid-dependents discounted monetary rewards more steeply. Additionally opioid-dependent individuals discounted money less steeply than a monetarily equivalent amount of heroin. Madden, Bickel, and Jacobs (1999) also examined delay discounting in opioid-dependent individuals by having them choose between smaller/immediate

amounts of money or opiates and larger/delayed amounts of money or opiates; their results were similar to Madden et al. (1997). Collectively, these results suggest that, in substance dependent individuals, substances of abuse (in the above examples heroin) are discounted more steeply than money. The same patterns of results have been found in cigarette smokers and cocaine users (Bickel, Odum, & Madden, 1999; Baker, Johnson, & Bickel, 2003; Coffey, Gudleski, Saladin, & Brady, 2003).

Odum and Rainaud (2003) examined delay discounting across different amounts of food, alcohol, and money. Their results showed that money was discounted less steeply than food and alcohol, which were discounted similarly. Odum, Baumann, and Rimington (2006) expanded on these findings by examining delay discounting across differing amounts of food and money. Their findings showed that small and large amounts of money were discounted less steeply than small and large amounts food. Odum and Baumann (2007) also examined the delay discounting of food, cigarettes, and money in cigarette smokers. They found that money was discounted less steeply than a monetarily equivalent amount of food and cigarettes, which were discounted similarly. Collectively, these findings refuted the notion that substances are discounted more steeply in people with a history of substance use and dependence. Instead, Odum and colleagues suggested that consumables in general (including but not limited to drugs and alcohol) are discounted more steeply than money. Estle, Green, Myerson, and Holt (2007) examined this by studying the delay and probabilistic discounting of money, candy, soda, and beer. The results from the delay discounting procedure showed that as delay increases, the value of all four commodities decreased. Consistent with Odum and Baumann's findings, the value of money decreased less steeply than the three

consumables, which lost their value at similar rates. Estle et al. suggested that consumables are discounted more steeply than money because they differ in terms of their fungibility, or the degree to which a commodity may be exchanged for other goods and or services.

Relation between Domain and Magnitude

The aforementioned collection of studies suggests that there are differential rates in delay discounting across commodity or outcome types, a phenomenon referred to as a domain effect. Recently, Holt et al. (under review) examined delay discounting across large and small amounts of commodities that differed in terms of their degree of fungibility and perishability. Fungibility was manipulated by constraining the degree of exchange for a particular reinforcer (Visa gift cards, gift cards to a grocery store, gift cards for jeans, and gift cards for pizza). All conditioned reinforcers (except the Visa) had a matched counterpart that differed in terms of perishability (candy, jeans, and pizza). Their results showed differential rates in discounting across small and large amount of reinforcers (magnitude effects), as well as differential rates in discounting across domain effects (both perishability and fungibility). The results suggested that fungibility *and/or* perishability could be moderating the degree to which magnitude effects occur.

At this point in time, there seem to be at least two main qualities of a commodity that moderate the rate at which it is discounted: domain and magnitude. Furthermore, there seems to be at least two separate characteristics of a commodity that moderate domain effects: fungibility and perishability. The specific characteristics of a commodity that contribute to magnitude effects, at this point in time, remain unclear. Lowenstein and Thaler (1989) argued that the magnitude effects are observed because there are separate

cognitive processes involved in making choices between small amounts of money in large amounts of money. Specifically, smaller amounts of money are conceptualized as spending money, or money that goes directly into your wallet, whereas larger amounts of money are conceptualized as savings, or money that goes directly into a savings account. Green and Myerson (2004) argued that magnitude effects are an artifact of the varying range in hypothetical monetary rewards studied in humans. However, this argument is not likely true, because Kirby (1997) found magnitude effects using small amounts of money (\$10). A second proposition by Green and Myerson was that when choosing during a delay discounting task, subjects may be actually calculating the rate of reward. For example, if choosing the smaller/immediate outcome is immediately followed by another choice, then the rate of reinforcement for choosing the smaller/immediate outcome is much higher than the larger/delayed outcome. However, all three of these potential explanations are post-hoc and difficult to test experimentally.

As Holt et al. (under review) discovered, there are at least two different aspects of a commodity that may moderate magnitude effects (fungibility and perishability). However, it is still unclear whether fungibility, perishability, or both, are necessary for moderating magnitude effects. Because there is a need for an empirically valid explanation for magnitude effects, and because both fungibility and perishability seem to moderate magnitude effects, the aim of the present study will be to isolate fungibility from perishability. Specifically, the present study will examine the delay discounting of small and large amounts of: Visa gift cards, gift cards to Old Navy, and gift cards for socks at Old Navy. These outcomes were chosen because (a) they differ in terms of their degree of fungibility and (b) they are non-perishable conditioned reinforcers.

Method

Participants

Participants in this study were of 16 men and 17 women (ages 18-22) from a midsized university in the southeast United States. The participants completed the study for participation credits in an undergraduate psychology course. Besides receiving course credit, there was no incentive to participate in the study, and there was be no penalty for withdrawing from the study.

Procedure

At the beginning of the study, each participant received a paper demographic questionnaire, which asked them about their age, class standing, and gender. Upon completing the demographic questionnaire, each participant received the entire delay discounting task. The task was administered using Qualtrics, a computer-based survey program. The discounting task consisted a six-step staircase questionnaire (adopted from Estle et al., 2006) with questions asking the participants to choose between a smaller/immediate amount of a commodity, and a larger/delayed amount of a commodity. The commodities in question included small (\$100) and large (\$1,000) amounts of: Visa gift cards, gift cards to Old Navy, and gift cards to Old Navy that could be exchanged for socks only. The delays used for the larger/delay condition included: 1 month, 6 months, 1 year, 3 years, and 10 years. At the start of each experimental condition, the smaller more immediate adjusting alternative was presented as half the size (\$50 or \$500) of the larger delayed commodity (\$100 or \$1,000). Depending on which alternative was chosen, the amount of the smaller more immediate alternative was increased or decreased 50% of the difference between the large and smaller amounts, in order to make the smaller more

immediate alternative more or less appealing. For example, if the participant chose the smaller alternative on the first choice iteration, the amount of that smaller/immediate commodity was decreased in the next choice set. This process was carried out for a series of six iterations using the same delay for the larger/delayed condition. The midpoint between the small and large commodity amount at the end of this iterative process for that particular delay condition was assumed to represent that particular person's indifference point, or the point at which the smaller/immediate alternative amount was assumed to be equal to the larger/delayed alternative. Once this indifference point was collected, the process was repeated keeping all of the variables the same except for the delay to the larger/delayed amount, **and/or** the amount of the commodity at question for the larger/delayed amount. At the completion of the experiment, each person had 30 indifference points: five indifference points (one for each delay) for the small and large amount conditions across all three commodity conditions. These indifference points were plotted on a graph, and AUC values were calculated for the small and large conditions across all three commodity conditions. Higher AUC values were assumed to represent shallower delay discounting, or a greater propensity to wait for the larger/delayed reward. Smaller area under the curve values were representative of steeper delay discounting, or a lower propensity to wait for the smaller/immediate reward. These six AUC values served as the dependent variables for statistical analysis.

Results

Syntax commands in SPSS 21 were used to create variables and calculate indifference points for all participants across all variable conditions (small and large amounts of all three commodities) at each delay. The syntax referenced the last iteration

of the questionnaire (the sixth step in the staircase method), and either added or subtracted fifty percent of the difference between the adjusting value in the present choice set and the adjusting value in the prior choice set. Median indifference points were then calculated for all delays across amount and commodity type conditions. The median indifference points were transferred to Sigma Plot to curve fit the two parameter model (Equation 2) $[V = A / (1 + k D)^S]$ using a non-linear least squares algorithm. For the VISA gift card condition, R^2 values were 0.956 and 0.995 for the small and large conditions, respectively. R^2 values for the small and large Old Navy gift card condition were 0.974 and 0.881, respectively. For the Old Navy gift card for socks condition, the R^2 values were 0.654 for the small condition, and 0.955 for the large condition. Indifference points were then proportionalized in Excel and then transferred to GraphPad to curve fit the data at the individual level using Equation 2, (see Table 1). Sigma Plot was used to compute Area Under the Curve (AUC) values, using Equation 4: $[(x_2 - x_1)(y_1 + y_2)/2]$.

A 2X3 repeated measures ANOVA was used to compare AUC values across commodity amounts (2) and commodity types (3). Mauchley's test of sphericity was not significant, showing that the assumption of sphericity was met: $\chi^2(2) = .938$, $p = .370$; there were no corrections needed for further analyses. There was a significant effect of fungibility, $F(1.88, 60.26) = 11.201$, $p < .001$. Post hoc analysis (across all commodity types) using a pairwise comparison with a Bonferroni correction showed that Visa gift cards were discounted the least ($M = .473$, $SD = .052$), and were significantly different only from Old Navy gift cards for socks ($p = .001$). Gift cards to Old Navy ($M = .418$, $SD = .052$) were also only significantly different from gift cards to Old Navy for socks ($p = .011$). Finally, Old Navy gift cards for socks were significantly different from both VISA gift

wards and gift cards to Old Navy ($p < .05$). There was also a significant magnitude effect $F(1, 32) = 13.641, p = .001$, wherein large commodity amounts ($M = .437, SD = .050$) were discounted less steeply than small commodity amounts ($M = .354, SD = .042$). Finally, there was no significant interaction between conditioned reinforcer magnitude and fungibility, $F(1.660, 53.119) = 2.268, p = .122$. Analysis of effect sizes (partial eta squared) showed a medium effect of both commodity amount and commodity type. Specifically, 26% of the variance in AUC values were explained by commodity type, and 29% of the variance in AUC values were explained by commodity amount. Correlations were also ran in order to determine whether or the delay discounting of all conditions were related. All commodity types were significantly and positively correlated with each other ($r \geq 0.43, p \leq .01$). Furthermore, within each commodity, the small and large amount conditions were significantly and positively correlated with one another ($r \geq .75, p \leq .01$).

Discussion

Past literature has found that larger amounts of a commodity are discounted less steeply compared to smaller amounts of a commodity, specifically money (Green, Myerson, & McFadden, 1997; Green, Myerson & Macaux, 2005). This phenomenon has been referred to as a magnitude effect. Also, different commodity types are discounted more or less steeply depending on their characteristics (Chapman & Elstein, 1995; Odum & Baumann, 2007; Odum & Rainaud, 2003). Generally, monetary rewards are discounted less steeply than are consumable rewards. This phenomenon has been referred to as a domain effect. Recently, it has been suggested that there may be an interaction between domain effects and magnitude effects, such that conditioned reinforcer fungibility and perishability both may moderate the degree to which magnitude effects

occurred (Holt et. al, under review). However, it is unclear as to whether or not reinforcer fungibility, reinforcer perishability, or both are responsible for moderating magnitude effects. The present study aimed to conceptually and parsimoniously replicate the aforementioned study conducted by Holt et al. (under review), by examining delay discounting across small and large amounts of conditioned reinforcers (VISA gift cards, gift cards to Old Navy, and gift cards to Old Navy that can only be exchanged for socks) in relation to magnitude effects.

The results of the current study showed evidence of delay discounting across all commodity types at both the aggregate level (see Figure 1) as well as the individual level. A correlational analysis showed that the delay discounting of each commodity type, small and large, was significantly and positively related. This suggests that the decision-making process was consistent across each condition. Additionally, there was a significant effect of commodity type wherein gift cards to Old Navy for socks were significantly different from both VISA gift cards and gift cards to Old Navy, but Old Navy gift cards and VISA gift cards were not different from each other. There were also statistically significant differences between commodity amounts, wherein the larger amounts were discounted less steeply than the smaller amounts. There was no a statistically significant interaction between commodity type and amount as originally hypothesized. However, a visual analysis of this relation suggests a potential interaction (see figure 2). Acknowledging that it is not statistically ethical to do so, omitting the Old Navy gift card condition from the statistical analysis also revealed a statistically significant interaction between large and small amounts of VISA gift cards and gift cards to Old Navy that may only be exchanged for socks. Specifically, the degree to which magnitude effects occurred was

moderated by the conditioned reinforcer fungibility; the VISA gift cards had large magnitude effects whereas the Old Navy gift cards that could only be exchanged for socks has negligible magnitude effects. However, partial eta showed only a small effect, wherein 6% of the variance in AUC values were explained by the interaction between commodity type and commodity amount.

It is possible that the current manipulations were not robust enough to detect an interaction across the three levels of conditioned reinforcer fungibility. For instance, it could be the case that students at JMU are interested in purchasing clothes, and Old Navy may be considered a fashionable store. If this is assumption is true, then gift cards to Old Navy may have a higher than expected value. Future research should consider making more salient manipulations across the different levels of conditioned reinforcer fungibility.

There are several considerations that must be taken into account when interpreting these results. First off, the indifference points for all large amount conditions were inaccurately computed (i.e., not calculated using the algorithm described in the method section). In constructing the survey, the small amount adjusting values were created first. For efficiency's sake, the adjusting values for each large amount condition were derived from the pre-existing small amount adjusting values in Qualtrics. When adjusting the large amount values, each monetary amount was rounded down to the nearest whole number and multiplied by 10. For example, if the adjusting value for the small amount condition was \$25.00, it would have been \$250.00 in the large amount condition. Although this specific example is not problematic, consider one in which the adjusting value is not an integer (e.g., 12.50). In the \$12.50 example, the correct large amount

adjusting value would have been \$125.00, but in this experiment, was calculated incorrectly (yet conservatively) at 120.50. The range in possible values that differed from the “true” values (the values that would have resulted from the algorithm) was from \$0.00-\$9.00. In conducting the analyses, the researchers did not see this as a problem because the error was in a conservative direction, such that the odds of finding a magnitude effect (if it exists) were stacked against them by using these values (e.g. lowering the “floor effect”).

The present study also brought to light an interesting confound that has yet to be considered in delay discounting research pertaining to monetary rewards. Conceptually, VISA gift cards are more fungible compared to the two Old Navy gift card conditions, but there is also a second level of fungibility: differential degrees of fungibility across small and large amount conditions. For example, there is a broader range of commodities that may be purchased with \$1,000 compared to \$100; therefore, \$1,000 is inherently more fungible than \$100. In order to provide further evidence for the importance of fungibility, the authors suggest that future studies manipulate fungibility while controlling for commodity amount. Such an experimental situation would mirror the traditional delay-discounting paradigms, but would manipulate the degree of fungibility across conditions (instead of amount). For example, subjects could be asked a series of questions about their preference between smaller/immediate amounts of money or larger/delayed amounts of money that can only be exchanged for X number of commodities. In the second condition, the subjects could be asked the same series of questions about the same amount of money, but instead the money may be exchanged for X+1 number of commodities, and so on. With this systematic manipulation of degrees of

fungibility comes a convenient ability to quantify, and an opportunity for a revision to Equation 2:

$$V = A * F / (1 + k D)^S (5)$$

This equation will allow for the degree of fungibility to moderate the effect of amount in relation to delay discounting. Specifically, higher F values should result in shallower discounting, whereas lower F values will result in shallower discounting.

Future research should also consider examining the effects of reinforcer perishability in relation to delay discounting, separate from reinforcer fungibility. Similar to the suggested fungibility research scenario, a perishability discounting task should include questions about conditioned reinforcer outcome types (e.g., gift cards) that differ in terms of their expiration dates. For example, subjects could be asked a series of questions about their preference between smaller/immediate amounts of money or larger/delayed amounts of gift cards that expire X months after their receipt. Manipulations across conditions can then increase the time to expiration, while holding the amount of the commodity constant. Presumably, the sooner the commodity expires (perishes), the steeper that commodity would be discounted. Hypothetically then, this quantifiable manipulation will also allow for a revision to Equation 2:

$$V = A * 1/P / (1 + k D)^S (6).$$

This equation will allow for the degree of perishability to moderate the effect of amount in relation to delay discounting. Specifically, higher P values should result in shallower discounting, whereas lower P values will result in steeper discounting.

In summary, it is apparent monetary outcomes are discounted less steeply than other outcome types. This is likely due to the fact that money is a unique commodity, one

that is complex and an artifact of economics. In order to further understand the complex relation between delay discounting and monetary outcomes, the unique aspects of money outcomes must be systematically controlled for, quantified, and manipulated across experimental situations (e.g. fungibility). Furthermore, it may also be useful to identify and quantify the qualities of non-monetary outcomes that yield differentially systematic patterns of delay discounting (e.g. perishability). Continuing the research in this direction will lead to a more unified theoretical understanding of this phenomenon.

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Table 1.						
<i>Individual R^2 values across commodity types</i>						
Participant	VISA small	VISA large	Old Navy Gift Card small	Old Navy Gift Card large	Old Navy Gift Card for socks small	Old Navy Gift Card for socks large
1	0.9419	0.9484	0.9378	0.9946	0.2339	0.9823
2	0.9141	0	0	0	0.1096	0.8743
3	0.9338	0.9969	0.9493	0.9886	0.9802	0.9655
4	0.9736	0.9546	0.9158	0.9545	0	0.995
5	0.8572	0.9757	0.4562	0.5991	0	0.6073
6	0.9398	0	0	0	0.9694	0
7	0.2147	0	0.7709	0.9158	0.7709	0.7651
8	0.9943	0.9801	0.9085	0.9119	0.8741	0
9	0.9608	0.9564	0.9231	0.921	0.6526	0.8902
10	0.9708	0.9038	0.5877	0	0.4906	0.2935

11	0.8799	0.8708	0	0.6658	0.02731	0
12	0.9939	0.8843	0.855	0.8271	0.6305	0.1865
13	0.2133	0.286	0.9269	0.8076	0.2778	0.8872
14	0.8499	0.8476	0.8736	0.7663	0.9706	0.02197
15	0.9141	0.9213	0.8743	0.6532	0.9804	0.908
16	0.9646	0.995	0.938	0.9843	0.9803	0.8856
17	0.9391	0.4915	0.9957	0.5315	0.8262	0.9527
18	0.8486	0.8133	0.818	0.9061	0.9627	0
19	0	0	0.9669	0.9648	0.9599	0.9468
20	0.9385	0.9835	0.987	0.8965	0.9928	0.1012
21	0.6736	0	0.04538	0	0.9094	0
22	0	0	0	0	0	0
23	0.8862	0	0	0.9982	0.9114	0.9368

24	0.9584	0.9449	0.9692	0.8181	0.7889	0.9844
25	0.9844	0.8251	0.8118	0.07567	0	0
26	0.9802	0.9381	0.5395	0.9147	0.5098	0.9329
27	0.9651	0.9813	0.8852	0.9524	0.4517	0
28	0.887	0.9834	0.9857	0.9376	0.6636	0.9892
29	0.9342	0.8962	0.95	0.9116	0.6962	0
30	0	0.6271	0.1735	0.1302	0	0.9141
31	0.0243	0.7814	0.8669	0.7323	0	0
32	0	0	0.8536	0.7868	0.8649	0.8218
33	0.9404	0.949	0.995	0.8814	0.7436	0.9022
Median	0.9338	0.87755	0.87025	0.8226	0.6799	0.79345

Figure 1.

Curve Fits Across all Conditions at Median Level

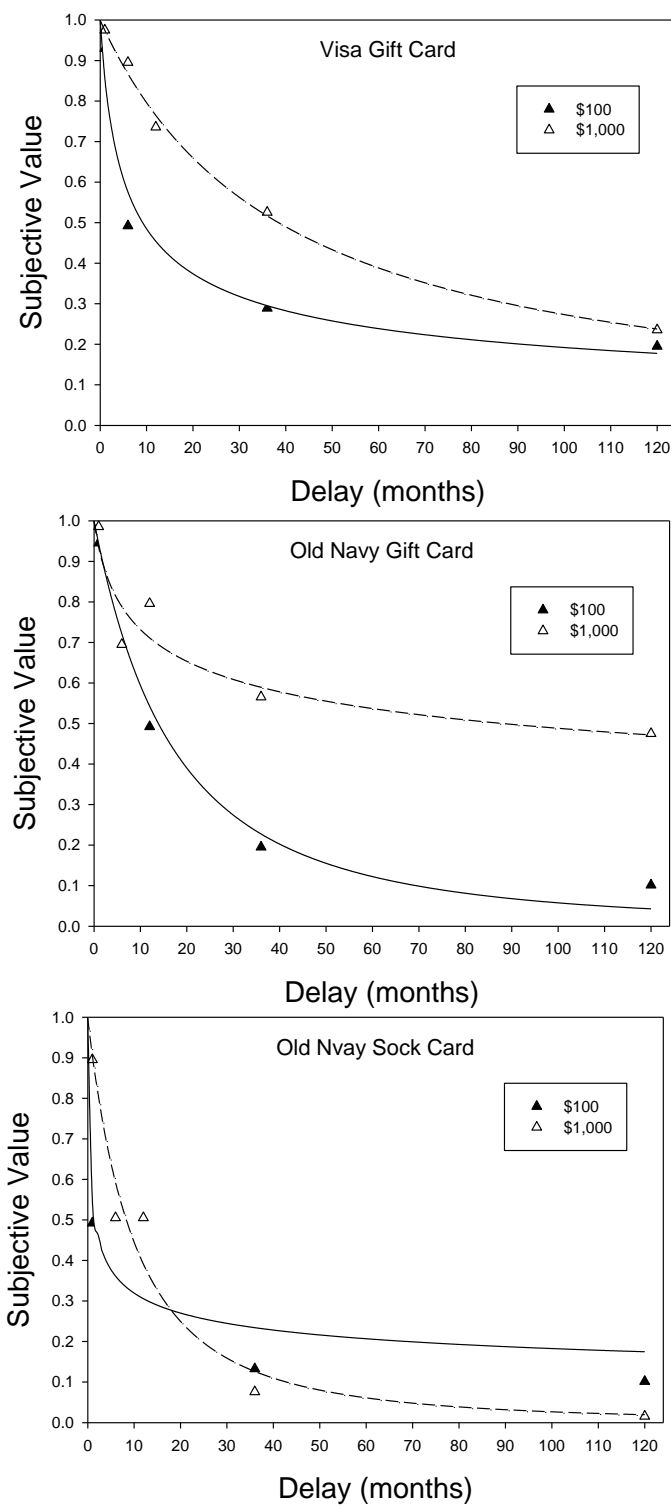
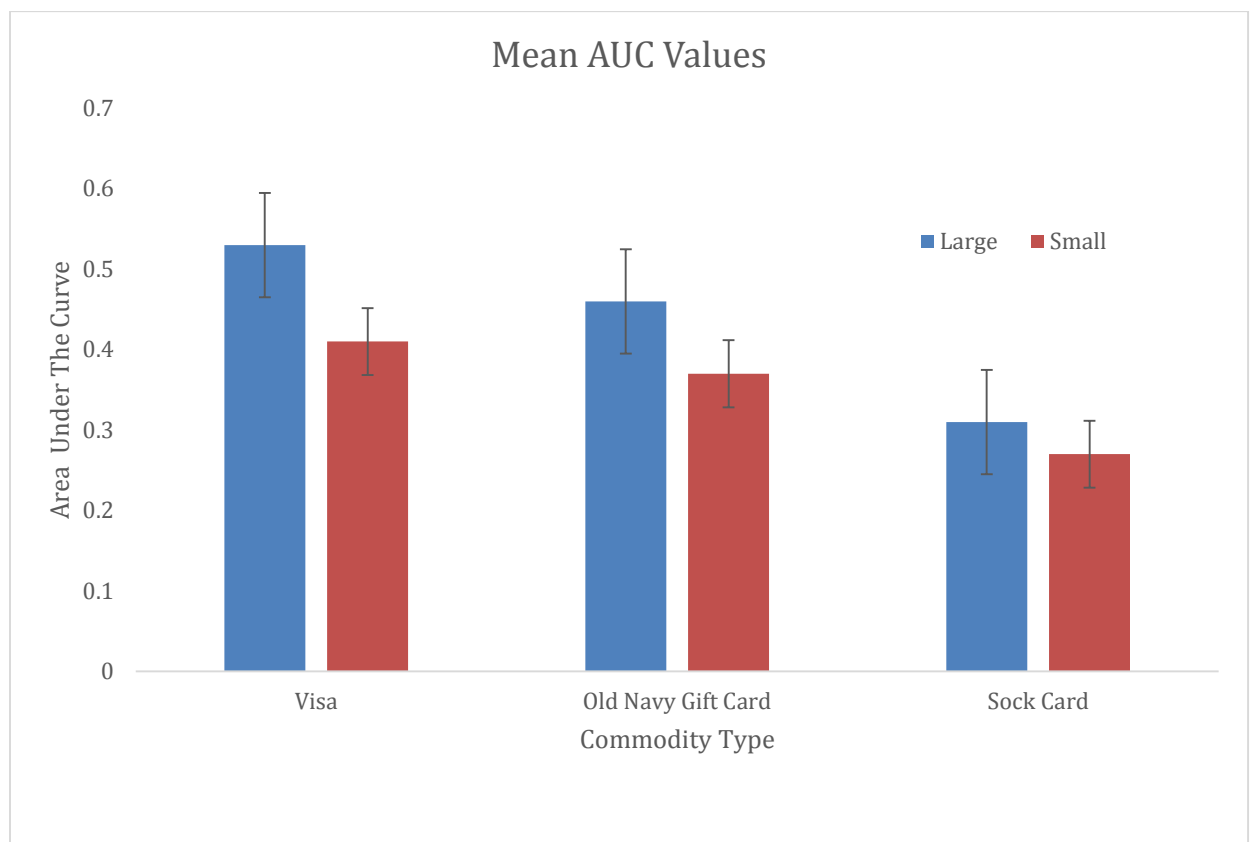


Figure 2.

Visual analysis of AUC values



Appendix A

Demographic Questions

1. What is your age?
2. What is your sex?
 - a. Male
 - b. Female
3. What is your current academic standing?
 - a. Freshman
 - b. Sophomore
 - c. Junior
 - d. Senior

Appendix B

Delay Discounting Example Questions

1. Which would you prefer?
 - a. \$500 right now
 - b. \$1,00 in 1 month
2. Which would you prefer?
 - a. \$750 right now
 - b. \$1,000 in 1 month